

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
19 June 2003 (19.06.2003)

PCT

(10) International Publication Number  
**WO 03/050825 A1**

(51) International Patent Classification<sup>7</sup>: **H01B 5/00**,  
5/08, 7/42

(81) Designated States (*national*): CA, JP, US.

(21) International Application Number: PCT/US01/48758

(84) Designated States (*regional*): European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR).

(22) International Filing Date:  
12 December 2001 (12.12.2001)

**Declarations under Rule 4.17:**

(25) Filing Language: English

— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations CA, JP, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR)  
— of inventorship (Rule 4.17(iv)) for US only

(26) Publication Language: English

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**Published:**

— with international search report

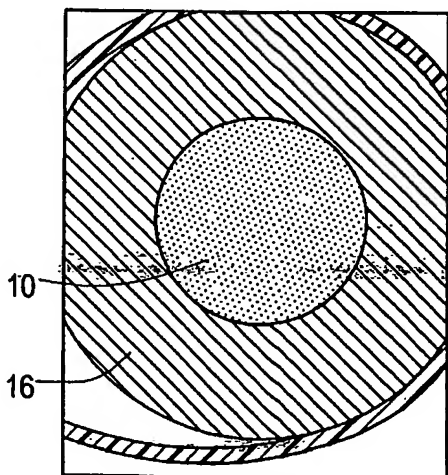
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*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

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(54) Title: HIGH VOLTAGE ELECTRICAL POWER TRANSMISSION CABLE HAVING COMPOSITE-COMPOSITE WIRE WITH CARBON OR CERAMIC FIBER REINFORCEMENT



Copper jacketed core wire 30 x

(57) Abstract: A high power electrical transmission cable having composite wires (10), wherein the wires have aligned reinforcing fibers (12) of carbon or ceramic embedded within a matrix material (14). A jacket of an electrically conductive material surrounds the core wire (10). The reinforcing fibers and the matrix material may be also electrically conducting materials. The matrix material may be aluminum, copper, a polymer, or an epoxy material.

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High Voltage Electrical Power Transmission Cable Having  
Composite-Composite Wire With  
5 Carbon or Ceramic Fiber Reinforcement

CROSS REFERENCE TO RELATED APPLICATIONS

N/A

10 STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR  
DEVELOPMENT

BACKGROUND OF THE INVENTION

15 High power electrical transmission cables are required for  
transmission of electrical power between power generating  
stations. Such cables typically have a reinforcing or supporting  
core wire made of steel. The steel core carries the load of the  
cable. Strands of an electrically conducting material are wound  
20 around the steel core. The strands are typically formed from  
aluminum or copper.

In cables having a steel core, the steel has a relatively  
high specific weight (7.8 gm/cc). Also, steel has a large  
coefficient of thermal expansion that can result in sagging of the  
25 cable. In extreme cases, thermal expansion can cause the cable to  
break. Another disadvantage arises from the use of a single  
load-carrying cable; failure of this single cable can be  
catastrophic to the entire cable.

In PCT International Publication No. WO 97/00976, a high  
30 power transmission cable is disclosed having a composite material  
core. This cable is stronger, more lightweight, and has a lower  
thermal expansion coefficient than cables using a steel core. The  
core material, however, has an elongation of only 1 to 1.5% and is

relatively brittle, leading to possible breakage and failure of the cable.

#### SUMMARY OF THE INVENTION

5       The present invention provides a high power electrical power transmission cable that is strong, lightweight and has a lower coefficient of thermal expansion. The cable is formed from composite-composite wires that comprise individual strands of a  
10       conducting material such as aluminum or copper in concentric or random arrangement with one or more cores of ceramic or carbon fiber reinforced composite wire. The composite core wire comprises aligned reinforcing fibers of carbon or ceramic embedded within a matrix material. Preferably, the matrix material is also a  
15       conducting material, such as aluminum or copper, although other materials can be used.

      The composite core wire may be formed by a continuous pressure infiltration process such as that disclosed in U.S. Patent No. 5,736,199, the disclosure of which is incorporated by reference herein. The concentric jacketing of the composite core  
20       wire(s) with the conducting material can be carried out in a number of ways. For example, the jacketing materials may be coextruded over the composite core wire(s). The jacketing material may be cold rolled longitudinally around and along the composite core wire(s). Alternatively, the composite core wire(s) may be  
25       inserted in a tube of the jacketing material, which may be drawn down over the composite core wire(s). Other methods of jacketing the composite core wire are possible.

#### DESCRIPTION OF THE DRAWINGS

30       The invention will be more fully understood from the following detailed description taken in conjunction with the accompanying drawings in which:

      Fig. 1 is a copy of a micrograph at 1000 X illustrating the composite core wire of the present invention;

Fig. 2 is a copy of a micrograph at 30 X illustrating a composite-composite wire comprising the composite core wire of Fig. 1 jacketed with a copper jacket;

Fig. 3 is a copy of a micrograph at 450 X more closely depicting the interface between the composite core wire and the copper jacket of Fig. 2; and

Fig. 4 is a schematic illustration of a plurality of composite core wires within a jacket.

#### 10 DETAILED DESCRIPTION OF THE INVENTION

According to the present invention, a high power electrical transmission cable is formed from composite-composite wires, each composite-composite wire comprising individual strands of a conducting material such as aluminum or copper in concentric, even, or random arrangement with one or a plurality of cores of ceramic or carbon fiber reinforced composite wire.

The composite core wire comprises aligned reinforcing fibers of carbon or ceramic embedded within a matrix material. Carbon fibers are preferred, because carbon is conductive and generally less expensive than ceramics. However, any suitable ceramic fiber, such as aluminum oxide, may be used if desired. Preferably, the matrix material is also a conducting material, such as aluminum or copper, although other materials can be used. For example, a polymer or epoxy material can be used for the matrix. Such a material is less conductive than, for example, aluminum or copper, but provides the same or similar strength and may be less expensive to manufacture.

The composite core wire may be formed by a continuous pressure infiltration process such as that disclosed in U.S. Patent No. 5,736,199, the disclosure of which is incorporated by reference herein. In this process, strands of carbon or ceramic fibers are introduced into a pressurized bath of molten matrix material through a lower orifice which provides a gradient such that the matrix material is liquid adjacent to the bath and solid

farthest from the bath, thereby preventing the pressurized molten matrix material from blowing out of the bath. In the pressurized bath, the matrix material infiltrates the fibers. The infiltrated fibers are drawn upwardly out of the bath into a pressurized environment in which the molten matrix material solidifies. Then the infiltrated, solidified core wire is drawn through an exiting orifice to an ambient environment. Using this continuous process, great lengths of composite core wire, suitable for use in power transmission cables, can be manufactured.

Fig. 1 illustrates a composite core wire 10 of carbon fibers 12 in an aluminum matrix 14. In this example, the composite core wire comprises approximately 12,000 individual strands of carbon or ceramic fiber. The solidified, infiltrated core wire has a diameter of approximately 1/16 inch. However, the number of strands of the fiber material and the finished diameter of the composite core wire may be chosen depending on the desired finished composite-composite wire, which depends on the power, voltage, and distance of the desired power transmission cable. Over long distances, power is usually transmitted at high voltages, at least 22 kV and often much greater.

If a polymer material is used for the matrix, the same continuous pressure infiltration process may be used, although the pressure required to cause the polymer matrix material to infiltrate the fibers may be lower than is required for a metal such as aluminum or copper.

The jacketing of the composite core wire or wires with the conducting material can be carried out in a number of ways. For example, the jacketing material may be coextruded over the composite core wire or wires. Alternatively, the jacketing material may be cold rolled longitudinally around and along the composite core wire or wires and welded to seal the longitudinal joint. In a further alternative, the composite core wire or wires may be inserted in a tube of the jacketing material, which may be drawn down over the composite core wire or wires. It will be

appreciated that other methods of jacketing the composite core wire are possible. The core wire or wires may be concentrically or evenly or randomly distributed within the jacketing material. The jacketed core wire may then be covered with any suitable  
5 insulating material and any other desired sheathing, as known in the art.

Fig. 2 illustrates one composite core wire 10 of Fig. 1 jacketed in a copper wire 16. Fig. 3 illustrates the interface between the composite core wire and the copper jacket of Fig. 2.  
10 Fig. 4 illustrates a plurality of composite core wires 10 in a random distribution within a jacket 14.

Strands of copper cable having carbon fibers and strands having aluminum oxide fibers were produced using the above-described high pressure, continuous infiltration process. The  
15 tensile strengths of the strands were above 50,000 psi, which is about 2.5 times that of pure copper. The weight of the reinforced strands was about 20 percent lower than that of pure copper.

A number of composite-composite reinforced wires formed in this manner can be assembled into a suitably sized power  
20 transmission cable in any desired manner. The composite-composite reinforced wires are relatively light in weight, having a specific weight ranging from 2.1 to 2.7 gm/cc, thereby leading to considerable weight savings over existing power transmission cables. The composite-composite reinforced wires also have  
25 relatively high strength and a low coefficient of thermal expansion.

The invention is not to be limited by what has been particularly shown and described, except as indicated by the appended claims.

## CLAIMS

What is claimed is:

- 5 1. A high power electrical transmission cable comprising:  
a composite core wire comprising aligned reinforcing fibers  
of carbon or ceramic embedded within a matrix material; and  
a jacket of an electrically conductive material surrounding  
the core wire.
- 10 2. The cable of claim 1, wherein the reinforcing fibers  
comprise aluminum oxide.
3. The cable of claim 1, wherein the reinforcing fibers are  
15 electrically conductive.
4. The cable of claim 1, wherein the matrix material comprises  
an electrically conductive material.
- 20 5. The cable of claim 1, wherein the matrix material comprises  
aluminum or copper.
6. The cable of claim 1, wherein the matrix material comprises  
a polymer or an epoxy.
- 25 7. The cable of claim 1, wherein the tensile strength of the  
fibers is greater than 50,000 psi.
8. The cable of claim 1, wherein the cable has a specific  
30 weight ranging from 2.1 to 2.7 gm/ cc.
9. The cable of claim 1, further comprising a plurality of  
composite core wires, each composite core wire comprising aligned

reinforcing fibers of carbon or ceramic embedded within a matrix material, the jacket surrounding the further composite core wire.

10. The cable of claim 9, wherein the plurality of composite  
5 core wires are evenly distributed within the jacket.

11. The cable of claim 9, wherein the plurality of composite core wires are randomly distributed within the jacket.

10 12. The cable of claim 1, wherein the composite core wire is concentric with the jacket.

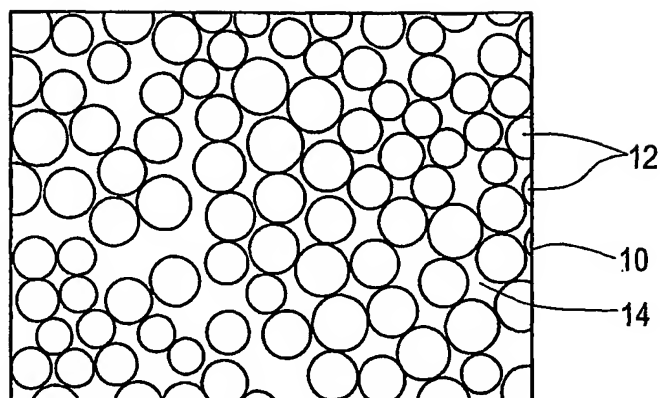
13. The cable of claim 1, wherein the core wire is sized to transmit at least 22 kV.

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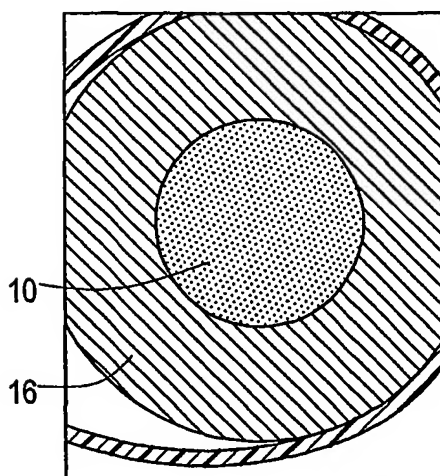
14. The cable of claim 1, further comprising an insulating sheath concentrically surrounding the jacket.



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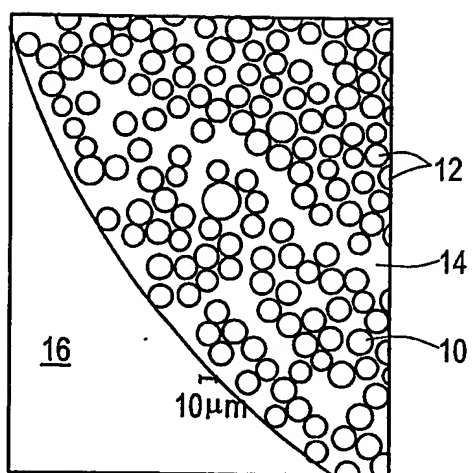
Core wire. Approx. 55 v/o P-25 carbon fiber in Al. matrix 1000 x

**FIG. 1**

Copper jacketed core wire 30 x

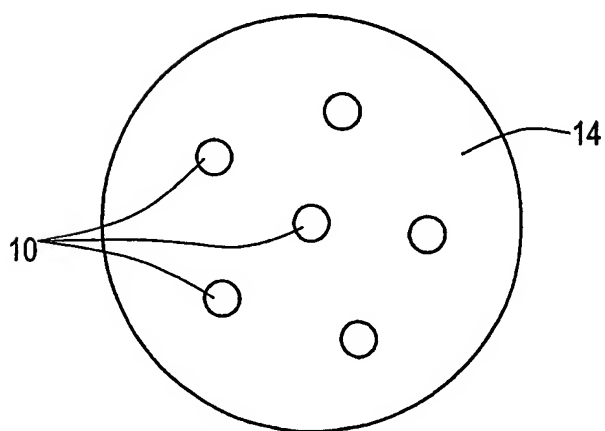
**FIG. 2**

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Interface between core wire and  
copper jacket  
450 x

**FIG. 3**



**FIG. 4**

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US01/48758

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(7) : H01B 5/00, 5/08, 7/42

US CL : 174/126.1, 126.2, 128.1, 128.1, 36

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 174/126.1, 126.2, 128.1, 128.1, 36

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched  
NONEElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
USPTO APS EAST**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 97/00976 A1 (MCCULLOUGH et al), 09 January 1997 (09.01.1997), page 3, lines 1-25; page 4, lines, 9-24; page 5, lines 1-3; and Figs. 1-2.	1-5, 7-14 -----
Y		6
Y	US 5,198,621 A (KOJIMA) 30 March 1993 (30.03.1993), cols. 1-14 and Figs. 1-5.	6
A	WO 95/27991 A1 (MESERVE) 19 October 1995 (19.10.1995), pages 1-12 and Figs. 1-4.	1-14
A	US 5,171,941 A (SHIMIZU et al) 15 December 1992 (15.12.1992), cols. 1-6 and Figs. 2-6.	1-14
A	US 3,647,939 A (SCHOERNER) 07 March 1972 (07.03.1972), cols. 1-14 and Figs. 1-6.	1-14

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

20 MARCH 2002

Date of mailing of the international search report

18 APR 2002

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## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US01/48758

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6,245,425 B1 (MCCULLOUGH et al) 12 June 2001 (12.06.2001), see entire document.	1-14